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DEPARTMENT OF ARMY
PROJECT No. 503-05-019
O.O. PROJECT No. TB3-0035
CONTRACT No. DA-11-022-ORD-1438

AD-054383

EXAMINATION
OF
FOREIGN ORDNANCE MATERIEL

[1955]

TITLE

METALLURGICAL INVESTIGATION OF AN 82 MM SHELL, MORTAR, H.E., w/EIGHT FINS, MODEL UNKNOWN, w/FUZE, PD, MODEL UNKNOWN: COMPLETE w/PROPELLANT INCREMENTS AND SHOTGUN SHELL TYPE IGNITION CARTRIDGE: COMM. CHINESE.

FMAM 2399

Technical Report
Report No. 9

armour research foundation of illinois institute of technology
technology center chicago 16, ill.

FOR
WATERTOWN ARSENAL
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METALLURGICAL INVESTIGATION OF AN 82 MM SHELL, MORTAR, H.E., w/EIGHT FINS, MODEL UNKNOWN, w/FUZE, PD, MODEL UNKNOWN: COMPLETE w/PROPELLANT INCREMENTS AND SHOT-GUN SHELL TYPE IGNITION CARTRIDGE; COMM. CHINESE.

FMAM 2399

Technical Report
Report No. 9

ARF Project Number B 062

Contract No. DA-11-022-ORD-1438
O.O. Project No. TB 3-0035
D/A Project No. 503-05-019
Report Number WAL: 700/22-3

Gary Steven
Senior Metallurgist

ARMOUR RESEARCH FOUNDATION
of
Illinois Institute of Technology
Technology Center
Chicago 16, Illinois

Authorized by:	ORDTB - Work performed under the technical supervision of Watertown Arsenal
O. O. Project Number:	TB 3-0035
Report Number:	9
Priority:	
Title of O.O. Project:	Investigation of Foreign Ordnance Materiel
D/A Project Number:	503-05-019
WAL Report Number:	700/22-3

TITLE

Mortar Shell, High Explosive

METALLURGICAL INVESTIGATION OF AN 82 MM SHELL, MORTAR, H.E., w/EIGHT FINS, MODEL UNKNOWN, w/FUZE, PD, MODEL UNKNOWN: COMPLETE w/PROPELLANT INCREMENTS AND SHOT-GUN SHELL TYPE IGNITION CARTRIDGE; COMM. CHINESE

FMAM 2399

OBJECT

To conduct a metallurgical examination of the subject shell and to compare it with equivalent U.S. shells.

SUMMARY

Technical and working drawings were prepared of the shell body and the tail fin assembly. The metallurgical investigation included chemical analysis,

hardness exploration, macro- and microexaminations, and transverse bend tests on specimens cut from the shell wall.

The shell body is sand cast from a high phosphorus gray iron. The exterior surfaces are rough machined; the tail and nose sections are threaded and the bourrelet areas are surface ground. The hardness, Rockwell "B" 93/94 (BHN-207), is that to be expected from an as cast shell of the given analysis.

The cartridge container is machined from 0.25% carbon steel with fins spot welded to its surface. The fins proper are rimmed, low C steel sheet which is bent into U channels.

CONCLUSIONS

1. In design, the subject Chinese 82 mm, HE, mortar shell is very similar to the U.S. prototype, namely, the 81 mm, HE, mortar shell, M 43A1. The wall thickness at the mouth of the Chinese shell, however, is heavier than in the domestic model.

2. The chemical analysis of the Chinese shell is typical of medium strength cast iron. The high phosphorus content points toward an intentionally brittle structure. Domestic shells are either hot forged, cold extruded, brazed from rolled sheet or cast from 0.45% carbon steel. Gray iron shells of this caliber have not been manufactured in this country.

3. The strength requirements for U.S. smooth-bored mortar shells, manufactures from steel castings is as follows:

Yield Strength in psi - 35,000 (min.)

Elongation in percent - 15 (min.)

Percent Reduction of Area - 25 (min.)

Transverse bend tests on specimens taken from the Chinese 82 mm shell indicate that the cast iron used is likely to be marginal with respect to the desired yield strength. It is further evident that gray iron will not meet ductility requirements of the U.S. specification.

4. The finish on the machined exterior surfaces and on the surface ground bourrelet lands corresponds to that found in domestic manufacture. On the other hand, the as-cast surface of the explosive cavity shows core sand pits and other blemishes that would not be acceptable in cast U.S. ammunition.

LOGBOOK

ARF Logbook No.C-3953 contains all laboratory data pertaining to the metallurgical investigation of the 82 mm, HE, mortar shell.

CONTRIBUTING PERSONNEL

Messrs. R.F. Borden, C.J. Carter, E. Klimek, V. Pulsifer, and E. Snider.

Respectfully submitted,

ARMOUR RESEARCH FOUNDATION OF
ILLINOIS INSTITUTE OF TECHNOLOGY

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Aberdeen, Maryland

INTRODUCTION

At the request of the Picatinny Arsenal,[1] a complete metallurgical evaluation was made of a cast iron mortar shell and its tail fin assembly. An FMAM identification number was assigned to this projectile by Aberdeen Proving Ground,[2] and the complete description is as follows:

FMAM 2399-Shell, Mortar, 82 mm, HE, w/eight fins, Model unknown, w/fuze, PD, model unknown, complete w/propellant increments and shotgun shell type ignition cartridge, Comm. Chinese.

The shell as received at Armour Research Foundation was inert and without fuze or propellant increments. The results of the examination of explosive charges and fuze train components are contained in the Picatinny Arsenal Technical Report No. 1997.

Work at the Foundation was performed under the technical supervision of the Watertown Arsenal Laboratory as part of an overall program on the metallurgical investigation of foreign ordnance materiel.

TEST PROCEDURE

The shell was examined visually and under the binocular microscope, to determine surface conditions and identify paint or lacquer coatings; the evidence of machining operations was also noted. The shell then was photographed and all dimensions were gaged; technical and shop drawings were prepared of the shell body and the tail assembly.

---

1. Letter File ORDBB-TE 386. 3/17/143. See Appendix A.
2. Letter File Apg. 386. 3/127, ORDBG-OTI. See Appendix A.

A longitudinal slice cut through the center of the shell was surface ground in preparation for hardness testing. A chemical analysis was made on all available components of the shell assembly. Photomicrographs were taken to show characteristic metal structures and the quality of the spot welds between the cartridge container and the fins. Since insufficient material was available from the shell wall for conventional tensile specimens, transverse bend specimens were substituted.

DATA AND DISCUSSION

A. Visual Observation and Design of the Shell

1. Shell body

The general appearance of the shell is shown in Figures 1 and 2. The body was cast in a sand mold and rough machined on all exterior surfaces. The machining feed was observed as 36 turnings/linear inch. The three bourrelet bands were surface ground (Brush surface analyzer readings: 65-60-30 micro-inch rms). The nose was threaded to receive the fuze. The wall of the explosive cavity presented the rough appearance of a cast core surface as shown in Figure 3. The shell then was coated externally with green paint.

A number of blemishes were observed on the tapered, exterior shell surface. It appears that originally these had been casting defects that were incompletely removed by subsequent lathe turning. A careful macroexamination, however, failed to uncover either deep pin holes or casting blow holes. There were no identifying markings stamped into or painted on the surface of the shell body.

Detail technical drawings and shop drawings of the 82 mm, HE, shell body are shown in Figures 4 and 5. Both interior and exterior contours of the shot body are very similar to the equivalent domestic shell, namely, the 81 mm HE mortar shell, M 43A1. The principal design difference appears to be the heavier wall in the nose of the Chinese shell, which accommodates a greater number of threads for the fuze insert. A point of secondary interest is the lack of an undercut at the base of the threaded tail section. One can surmise that the bore was not tapped on an automatic machine tool, but rather was hand tapped.

2. Fin Assembly

The fin assembly also resembles the American counterpart. It is shown in the photographs, Figures 1 and 7 and the detail drawing, Figure 6. It consists of four double blades which are spot welded in three places to the hollow cylindrical shaft. This cartridge container in turn is threaded at the front end and screwed into the base of the shell. Sixteen holes are drilled through the wall of the cartridge container. One half of these holes are located between the double fins; the other half coincided with previously punched perforations in the bottom of the U shaped fin channels. (See Fig.7.)

B. Metallurgical Characteristics

1. Chemical Analysis

a. Shell Body

The chemical analysis of the shell body is shown in Table I. This composition is representative of medium strength gray cast iron with uncommonly high phosphorus content. This element may have been added purposely, in order to produce a frangible shell body. In domestic practice, the 81 mm HE mortar shell is either cast from 0.45% carbon steel or forged (cold extruded) from plain carbon steel of the same grade.

b. Tail Fin Assembly

Table I lists the chemical analysis of the drilled shaft (cartridge container) and the spot welded fins. It shows that the cartridge container is fabricated from 0.25% carbon steel and that the fins are formed from rimmed, low carbon steel. In American practice the cartridge container is a screw machine product, requiring free machining steel such as FS-1117 grade. Furthermore, mechanical property requirements of the fins prescribe WD 1020 steel for this application.

2. Acid Etch Test

a. Tail Fin Assembly

A longitudinal section through the tail fin assembly was hot acid etched in 50:50 HCl. A photomacrograph of this section is shown in Figure 7. It shows that the cartridge container is machined, drilled, and bored from bar stock. The fins proper are blanked from 0.070 inch steel sheet, bent into tapered U channels and spot welded to the hollow shaft in three places. The extent of the heat affected zone, resulting from spot welding, varies appreciably from one weld to the other. Weld "C" in the lower right hand corner of Figure 7 shows shallow penetration; the weld next to it, "B", extends nearly through the wall of the cartridge container. This can be explained, however, by using an analogy with current domestic manufacturing practice. In order to locate the fins accurately, spot welding is preceded by a tack welding step and a re-alignment of the fin positions and angles.

3. Metallographic Examination

a. Shell Body

The photomicrographs in Figure 8 show unetched microstructures of the cast iron shell. Figure 8a represents a sample taken from the nose of the shell body and Figure 8b characterizes the cast iron structure in the tail end. The corresponding ASTM* classifications are Type A and B, (Figure 8a) and

* ASTM designation A - 247, 1942.

predominently A (Figure 8b). In both photomicrographs the graphite flakes are size 5. Different solidification rates in the two sections of the shell body may well account for this slight difference in structure. Figure 9a shows a Nital etched section of the cast iron constituents at high magnification. The photomicrograph contains graphite flakes embedded in a predominently pearlitic matrix. This matrix is interspersed with networks of the iron phosphide eutectic (steadite). The microstructure thus is typical of a sand cast gray iron of the given chemical analysis.

b. Tail Assembly

Figure 9b shows in juxtaposition the normalized structure of the 0.25% carbon steel (cartridge container) and the rimmed, low carbon steel of the fin connecting section. In the spot welded zone between these two components columnar grains replace the equiaxial grains of the original structure (Figures 9c and 9d). Localized, excessive grain growth in the 0.25% carbon steel (Figure 9c) indicate areas which had not reached the fusion point. The large dendrites observed in the defective spot weld (Figure 9d) furnish a plausible explanation for the hole in the welded zone (Weld "A" in Figure 7). With too high current density or improper timing of the welding cycle, the metal is overheated and the formation of a shrinkage cavity becomes a likely contingency.

4. Mechanical Properties

a. Shell Body

A hardness survey was made on a longitudinal slice cut through the center of the 82 mm HE shell body. The readings recorded in Figure 10 are both Rockwell "B" hardness 93.5 - 94, and Brinell hardness number 207. There was not sufficient material available in the shell walls to machine conventional tensile specimens. Therefore, transverse bend specimens 1/4" x 1/4" x 3" long were obtained from the location shown in Figure 10. These beams were center loaded and deflection was noted at each load. The results of this test are recorded in Table II. The maximum fiber stresses were then calculated for a center-loaded rectangular beam.

$$S = \frac{3}{2}\frac{Pl}{bh^2} \quad \text{where}$$

P = concentrated load, in lbs.
l = span between supports, in inches.
h = beam thickness, in inches.
b = beam width, in inches.

The fiber stress-deflection curve is plotted in Figure 11. The rupture stresses in two specimens were 71,200 psi, and 74,000 psi, respectively.

The transverse rupture strength data and tensile strength of the material cannot be correlated by analytical calculation; however, comparative test results from a number of high and low strength cast irons have established a ratio of rupture strength to tensile strength of approximately 2:1. Accordingly, the estimated tensile strength of the cast iron used in the shell body is 36,000 to 37,000 psi. This value shows good correlation with the observed Brinell hardness (BHN - 207).

b. Fin Assembly

The following Rockwell "B" hardness readings were obtained on the fins:

R_B	47	47	47	47

This hardness does not meet domestic specifications calling for a hardness of R_B 60 (min.). The cartridge container showed the following hardness:

R_B	77	79	80	78	77

The mechanical strength of the spot weld attachment was tested by using the tensile fixture shown in Figure 12. The spot weld failed in shear at 1875 pounds tensile pull through the wall of the fin. The spot weld proper is stronger than the base material and therefore is adequate for the application. The proof test for this joint in domestic shell manufacture is 500 pounds tensile pull.

GENERAL CONSIDERATIONS

The subject Chinese 82 mm, HE, mortar shell was cast from high phosphorus gray iron. It was rough machined and the bourrelets were surface ground.

In design, the Chinese mortar shell is very similar to its U.S. prototype, namely, the 81 mm, HE, mortar shell. The latter, however, is cast from 0.45% carbon steel. Although standard tensile specimens could not be obtained from the shell body, transverse bend tests seem to indicate that the mechanical strength of the shell is marginal with respect to domestic specification (35,000 psi). It does not meet the requirements for ductility. The fin assembly also resembles the domestic counterpart. The low carbon, rimmed steel of the fins proper does not come up to minimum hardness requirements for the corresponding material in domestic manufacture; however, the cartridge container is well designed and the spot welded attachment is sufficiently strong by domestic standards.

It appears that a casting method could offer sizable advantages in the fabrication of mortar shells. Shell molding in particular could produce cast iron shell bodies within specified dimensional limits. All external machining would thus be eliminated with the exception of the bourrelets which could be surface ground directly on the castings. Furthermore, finishing of the shell would involve a single chucking on an automatic lathe. The consecutive operations might consist of boring and tapping the mouth and tail sections. It is believed that cast shells could be produced at appreciable cost savings.

The strategic importance of a shift in fabrication method should not be overlooked. In case of war, the production of mortar shells then would not be dependent upon primary steel making capacity or the availability of certain sizes of bar stock. It would also free machine tools now used in generating the external contours of the shell.

TABLE I

CHEMICAL ANALYSIS

Component		Composition in Per Cent by Weight									
	Graphitic Carbon	Total Carbon	Mn	Si	S	P	Ni	Cr	Mo	V	Cu
Body of the 82 mm HE Mortar Shell	2.61	3.14	10	2.00	0.087	0.723	0.01	0.01	0.01	0.01	0.02
Fin Assembly – Cartridge Container		0.25	0.65	0.23	0.033	0.030	0.03	0.02	0.01		0.03
Fin Assembly – Fins		0.07	0.35	0.02	0.040	0.014	0.02	0.02	0.01		0.04

TABLE II

TRANSVERSE BEND TEST

Specimen size: 0.253" x 0.253" x 3" long

Load in Lbs.	Maximum Fiber Stress in psi	Center Deflection in Inches
100	28,600	0.0025
150	43,000	0.0035
200	57,200	0.0055
250	71,600	0.008
(260)	74,000*	-

* Rupture strength of specimen No. 2.

APPENDIX A

Letter File: ORDTB-TE 386.3/17-143

ORDBG-OTI Apg. 386.3/127

ABSchilling/rp/6178

IN REPLY REFER TO: ORDTB-TE
386.3/17-143

Armour Research Foundation
Chicago 16, Illinois

ATTENTION: Mr. Verne Pulsifer

SUBJECT: Metallurgical Examination of Foreign Material

Gentlemen:

There is being forwarded, for metallurgical examination and preparation of detailed drawing one (1) Shell, HE 82 mm with 8 vane fin for Mortar, AIC Z70MA (Chinese).

Request for an FMAM identification number for this item has been made to Aberdeen Proving Ground, Maryland. This number, which is their Inventory number for Foreign manufactured ammunition will be communicated to you upon receipt for use, with nomenclature, on all work connected with this item.

The above round is part of a shipment of inert metal items for examination under contract with Watertown Arsenal.

The assigned Watertown sub-number under WAL 700/22-3 is requested for use as a cross reference on reports being prepared at Picatinny Arsenal covering the general examination of this round. The assigned Picatinny Arsenal Technical Report Serial Number covering local examination is 1997.

FOR THE COMMANDING GENERAL:

Very truly yours,

W.R.Carson
Assistant

IN REPLY REFER TO: Apg. 386.3/127 H Himmer/prs/29282

ORDBG-OTI 19 July 1954

TO: Armour Research Foundation of
Illinois Institute of Technology
Technology Center
Chicago 16, Illinois

ATTN: Mr. Gary Steven

REFERENCE: B 062, ltr dtd 2 July 1954

1. The 82-mm mortar shell described in your letter referenced above has been identified as follows:

FMAM-2399 Shell, Mortar, 82-mm, HE, w/eight fins, Model unknown, w/Fuze, PD, model unknown; complete w/propellant increments and shotgun shell type ignition cartridge, Comm. Chinese

Request that this nomenclature and stock number be used in any future reference to this item and in the report covering its analysis.

2. It has been noted that the two photos of the item listed are classified CONFIDENTIAL. In accordance with the latest criteria for classification of technical intelligence, a copy of which has recently been furnished Watertown Arsenal, general view photos of the complete item are unclassified unless specific instructions to the contrary are furnished with the item.

FOR THE COMMANDING GENERAL:

LEO J. SOBCZAK
Capt, Ord. Corps
Chief, Ord. Tech Intel Ser

CC: CO, Watertown Arsenal
ATTN: ORDBE-L

Figure 1. Plan view of the 82 mm HE mortar shell w/eight fins.

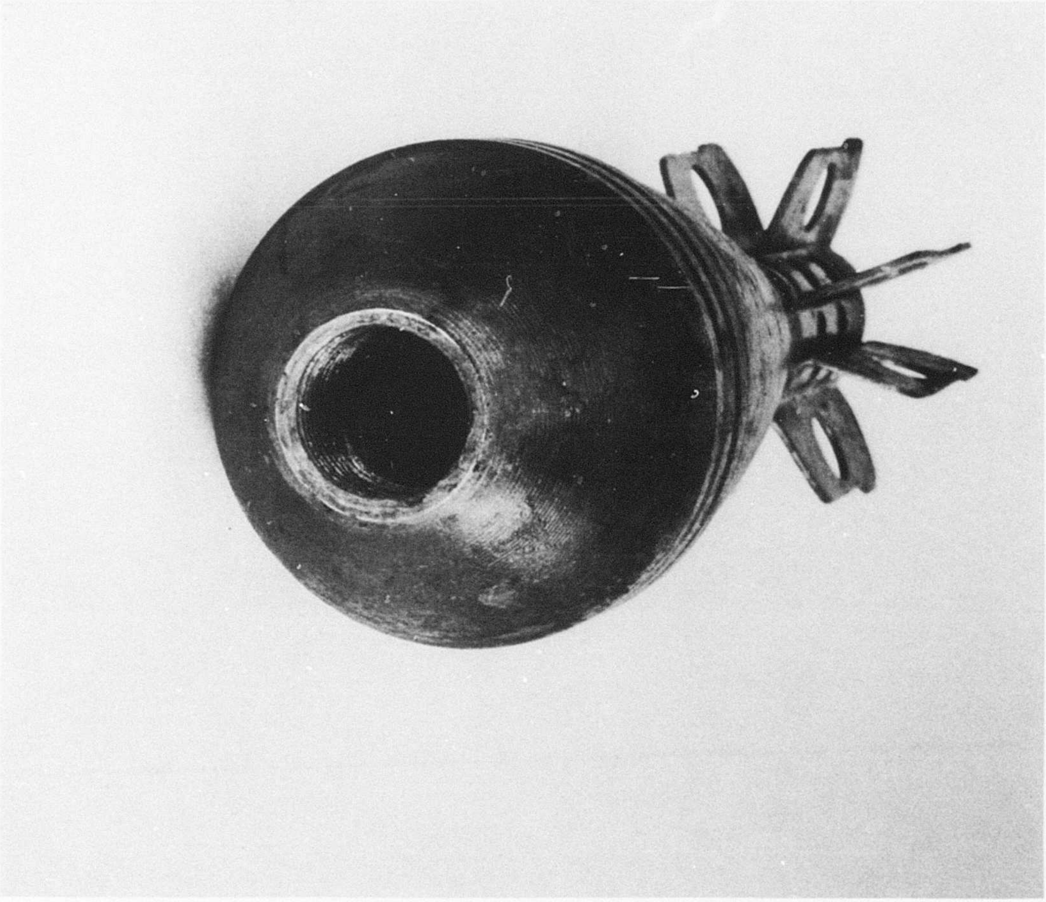

Figure 2. Top view of the 82 mm HE mortar shell showing threaded nose portion (receptacle for a fuze).

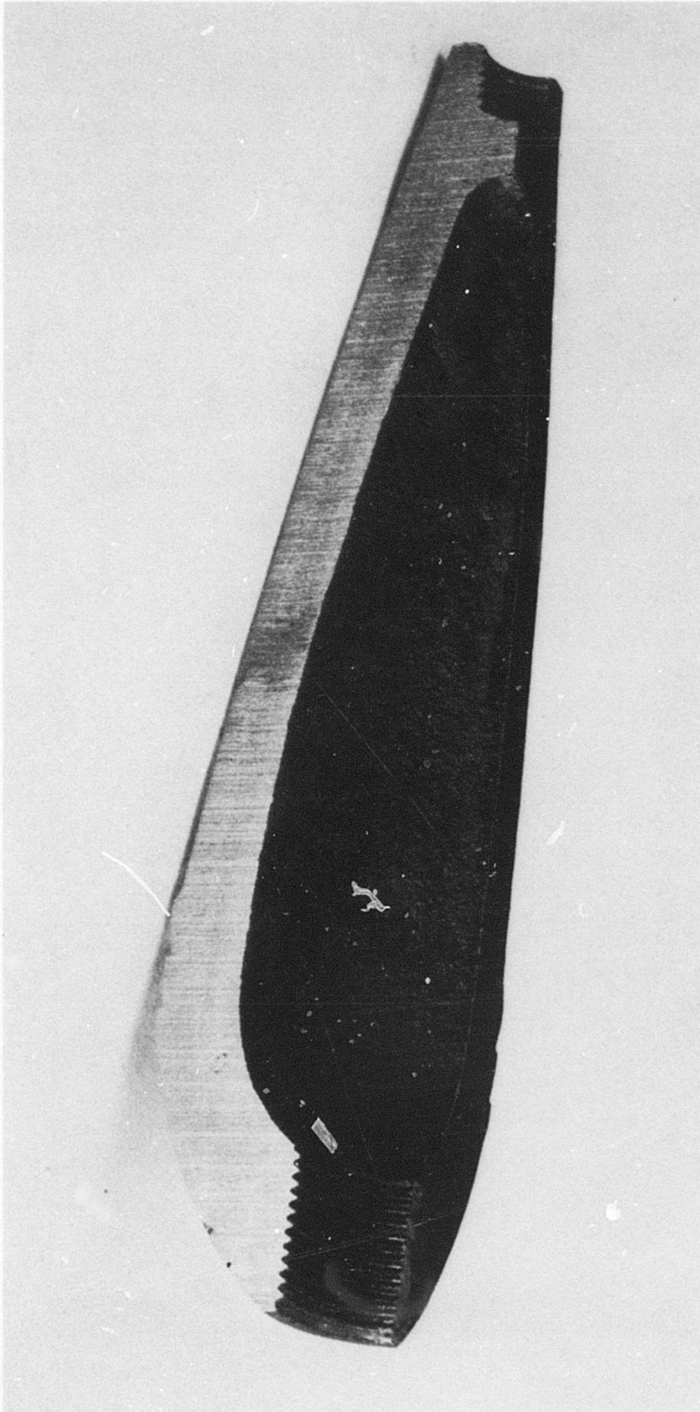

Figure 3. One quarter section of the 82 mm HE shell body showing the surface appearance of the explosive cavity. Note the rough wall of the shell I.D.

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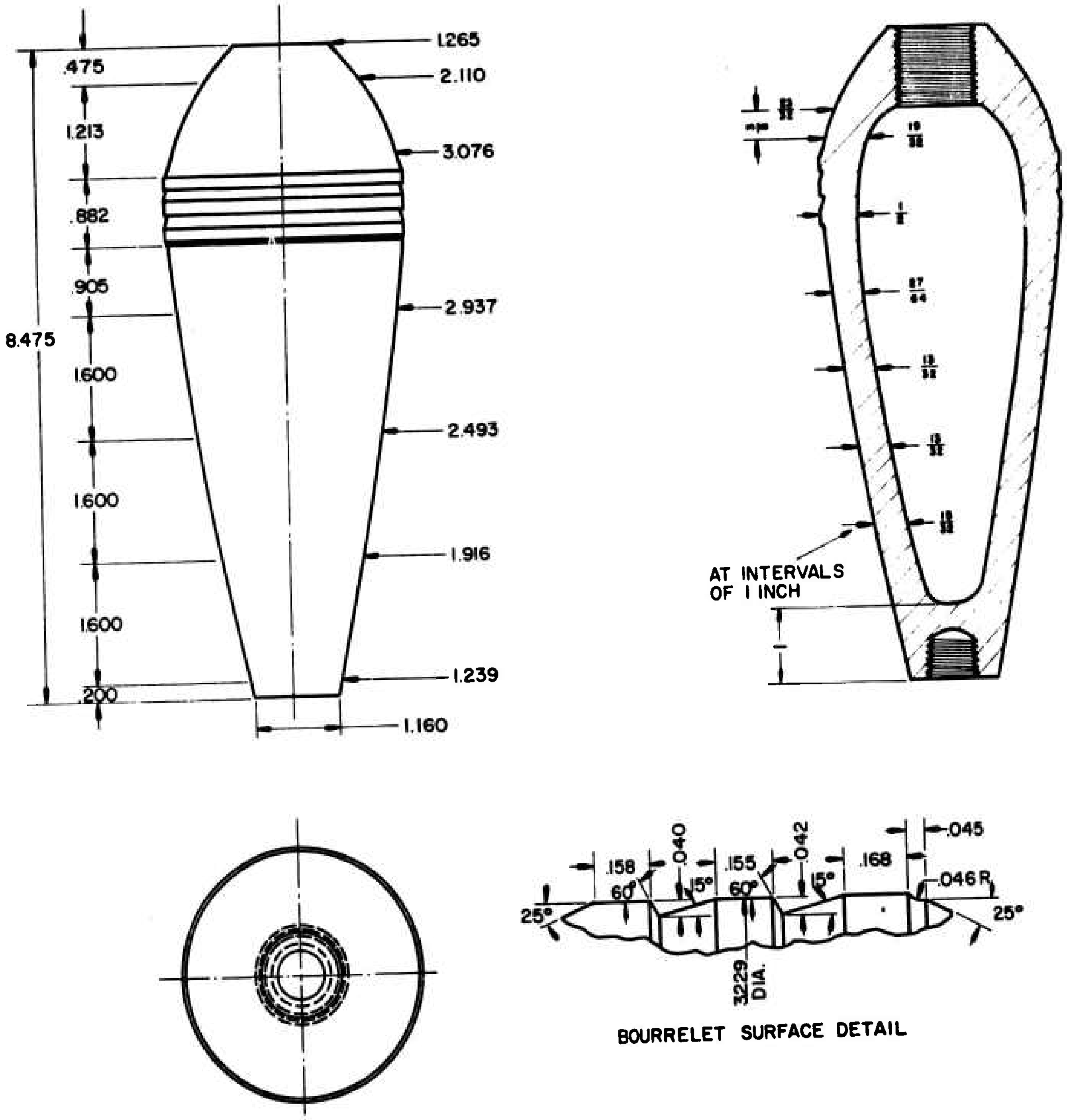

Figure 4 – Chinese 82 mm Mortar Shell (HE)

CALIBER: 82 mm
IDENTIFICATION CODE: AIC Z70MA (FMAM 2399)
TYPE: High Explosive (HE)
WEIGHT: 6.26 lbs.
BURSTING CHARGE:

FUSE:
KNOWN USING WEAPON:

REMARKS:

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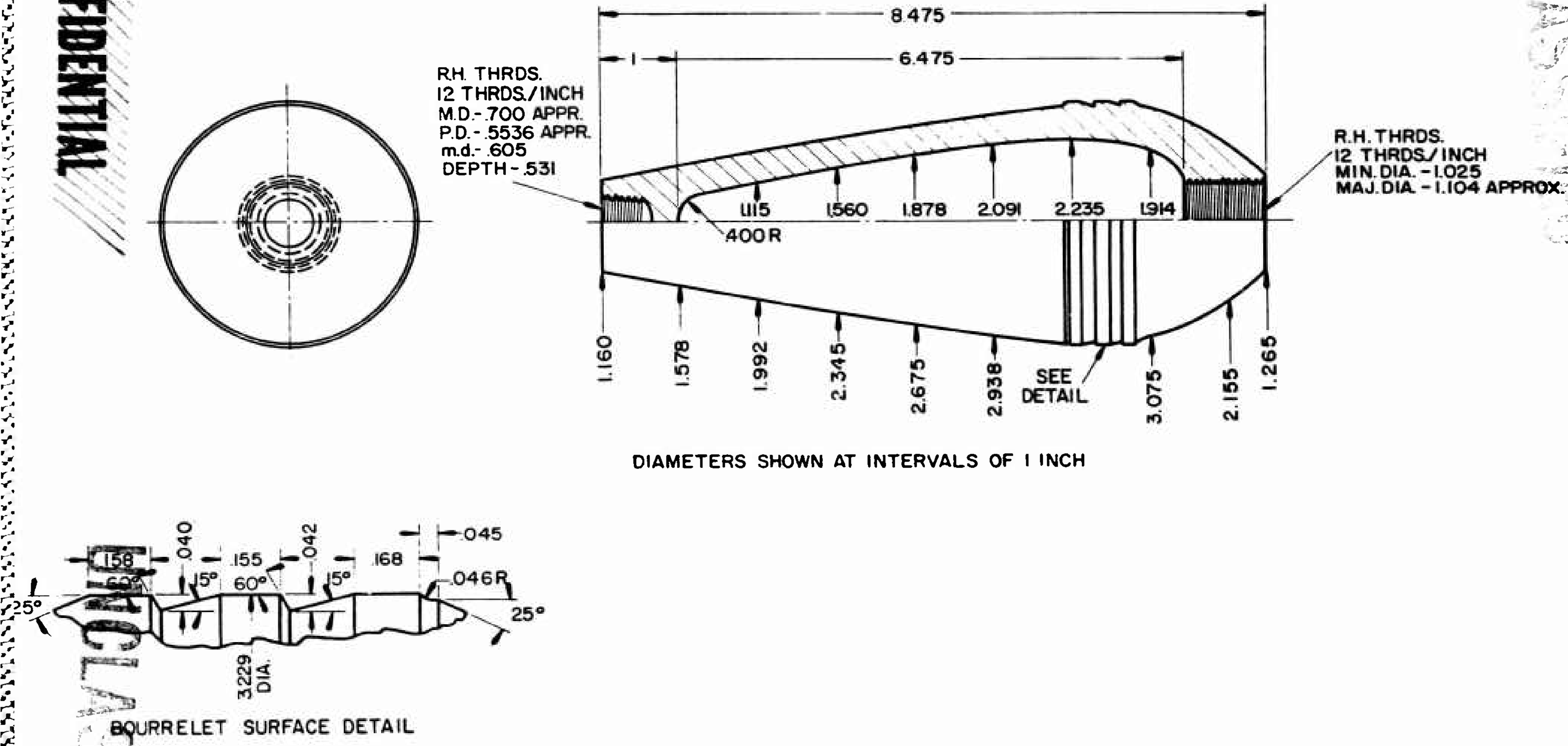


FIG.5 - DETAIL DRAWING OF 82 MM MORTAR SHELL BODY
AIC Z 70 MA (CHINESE) FMAM 2399

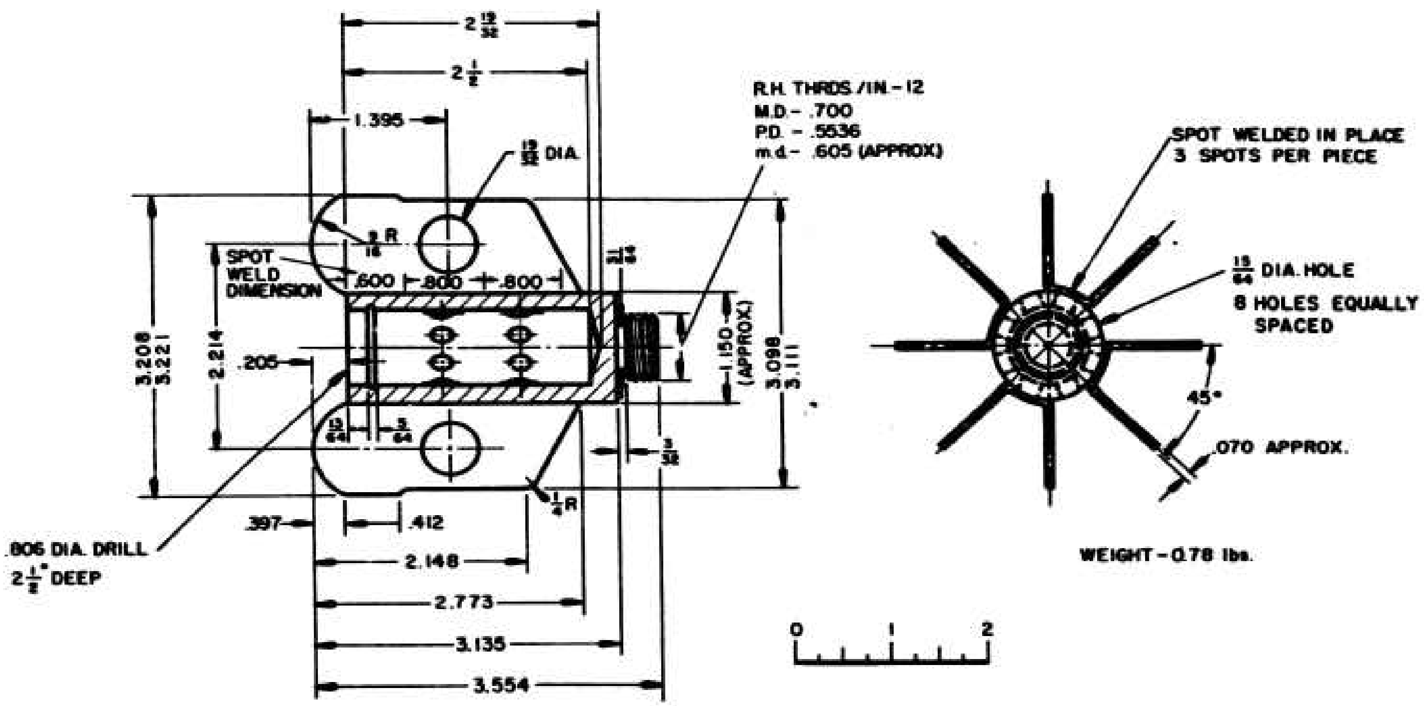
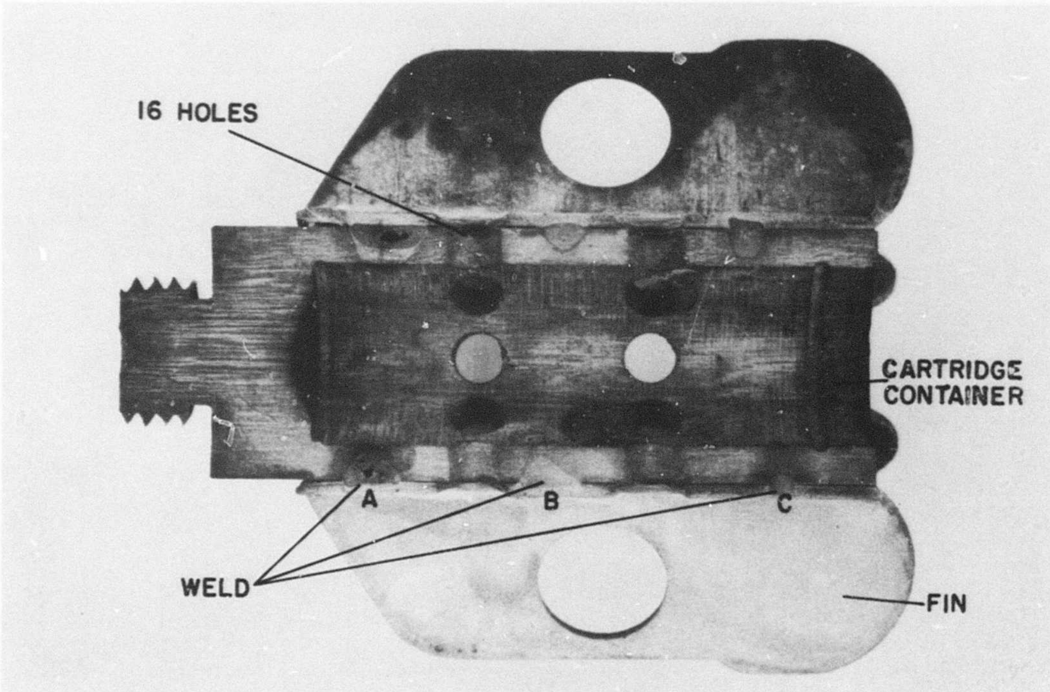


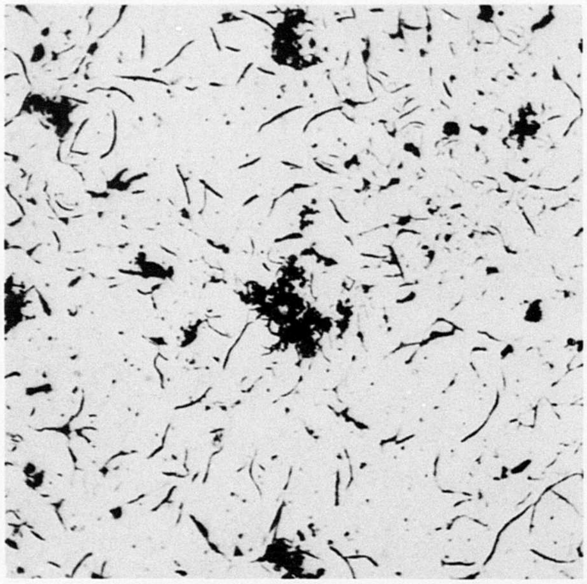
FIG. 6 — DETAIL DRAWING OF 8 VANE FIN FOR 82 MM MORTAR SHELL (CHINESE). FMAM 2399



Neg. No. 9355

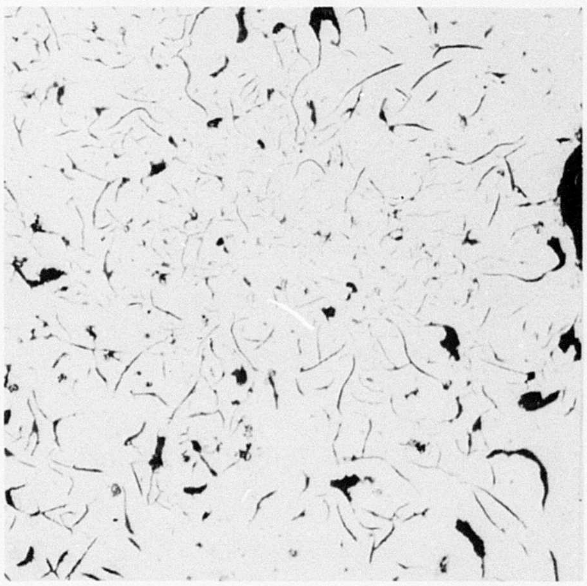
X 1-1/2
Etchant: 1:1 HCl

Figure 7. Hot acid etched longitudinal section of the Fin Assembly. Note the porous spot welds which form the front attachment between the cartridge container and four bent sheet stampings which form the fins proper.



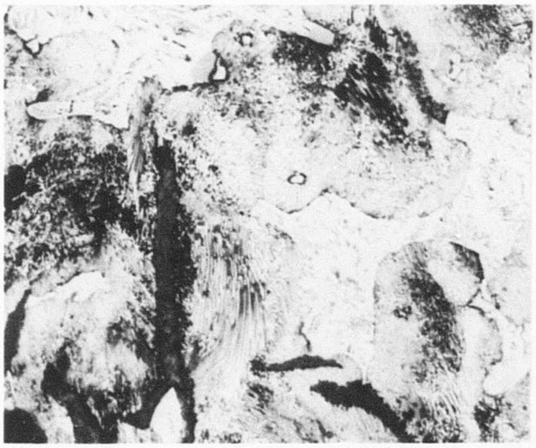
ASTM -A 247 1942

X100 - a - Unetched
Neg. No.9492



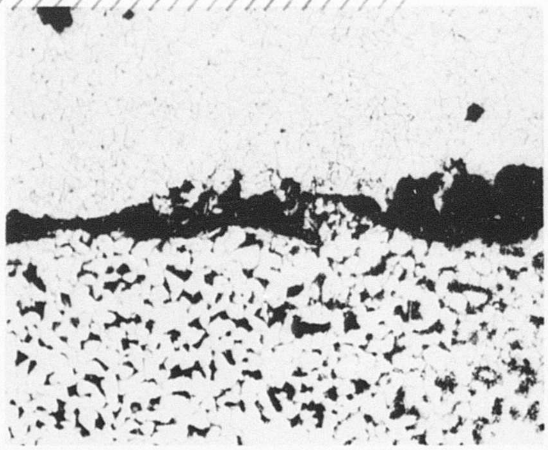
X100 - b - Unetched
Neg. No. 9493

Figure 8. Microsections of specimens taken from the nose of the cast iron shell body (a) and the tail (b), respectively.



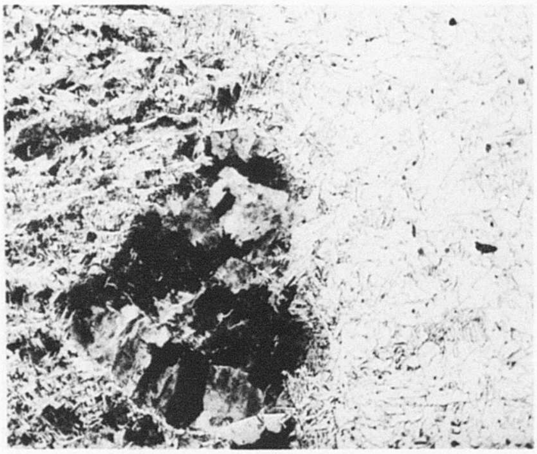
X500 - a - 2% Nital
Neg.No. 9498

Cast iron structure in the shell body showing graphite flakes in a predominently pearlitic matrix; dispersed iron phosphide network (steadite).



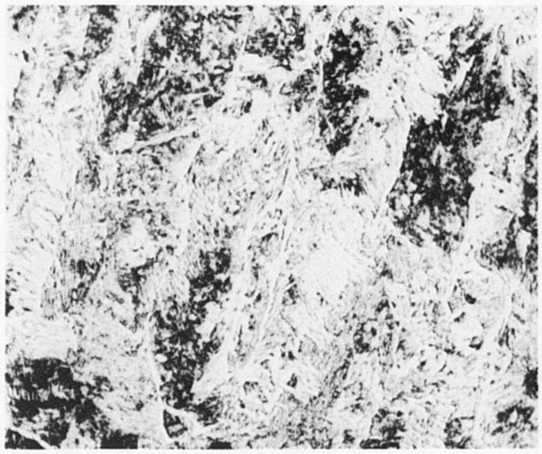
X100 - b - 2% Nital
Neg.No. 9494

Not spotwelded region of joint between rimmed, low C steel fin (top) and the 0.25% carbon cartridge container (bottom).



X100 - c - 2% Nital
Neg.No. 9495

Spotwelded zone between a fin and the cartridge container. Note grain coarsening in the 0.25% carbon steel tube.

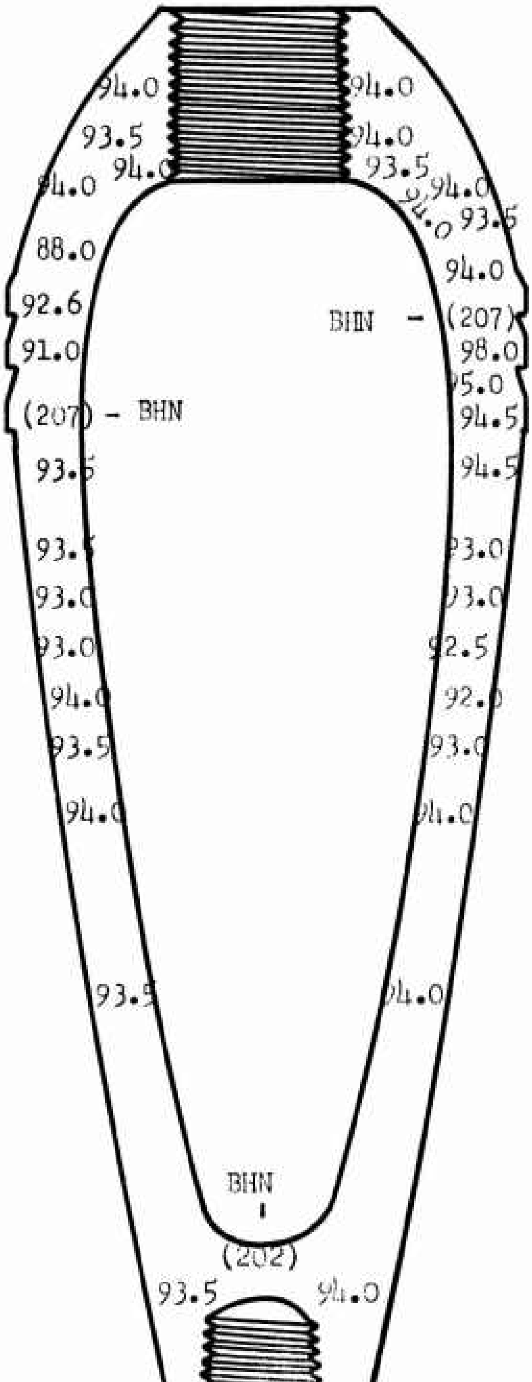


X100 - d - 2% Nital
Neg.No. 9496

Photomicrograph of the heat affected zone in the defective spotweld "A" in Figure 7. Note the pronounced columnar grains showing typical Widmanstaetten structure.

Figure 9. Photomicrograph of a section through the body of the 82 mm, mortar shell and of the spot welded zone from the attachment of the fins to the cartridge container.

Fig. 10. Hardness Survey on a longitudinal slice cut through the centerline of the 82 mm, HE, shell body. Rockwell "B" hardness readings, (Brinell hardness numbers).



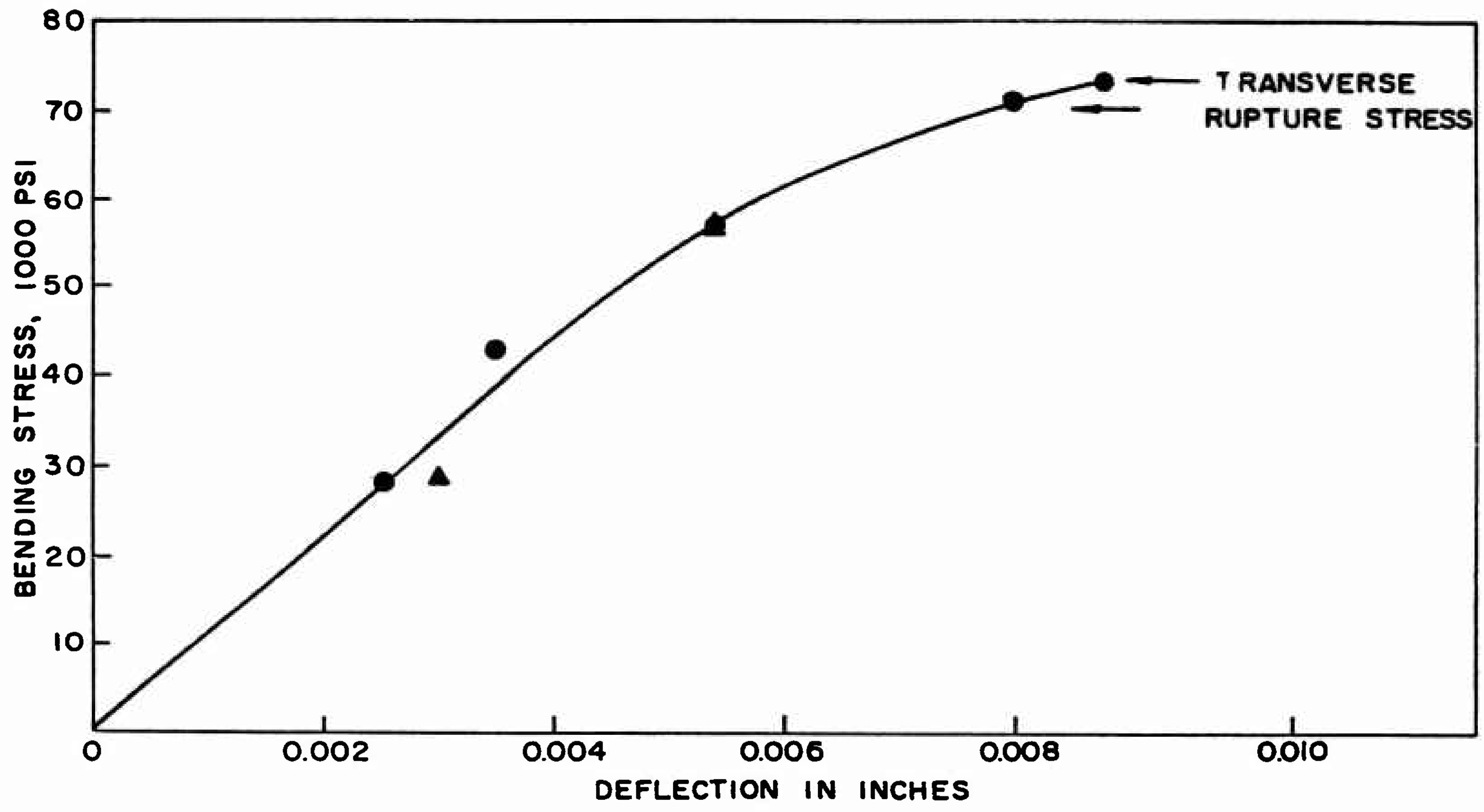


FIG. 11 - TRANSVERSE BEND TEST ON SPECIMENS CUT FROM THE WALL OF THE GRAY CAST IRON SHELL BODY. 82 MM, HE, MORTAR SHELL, FMAM 2399

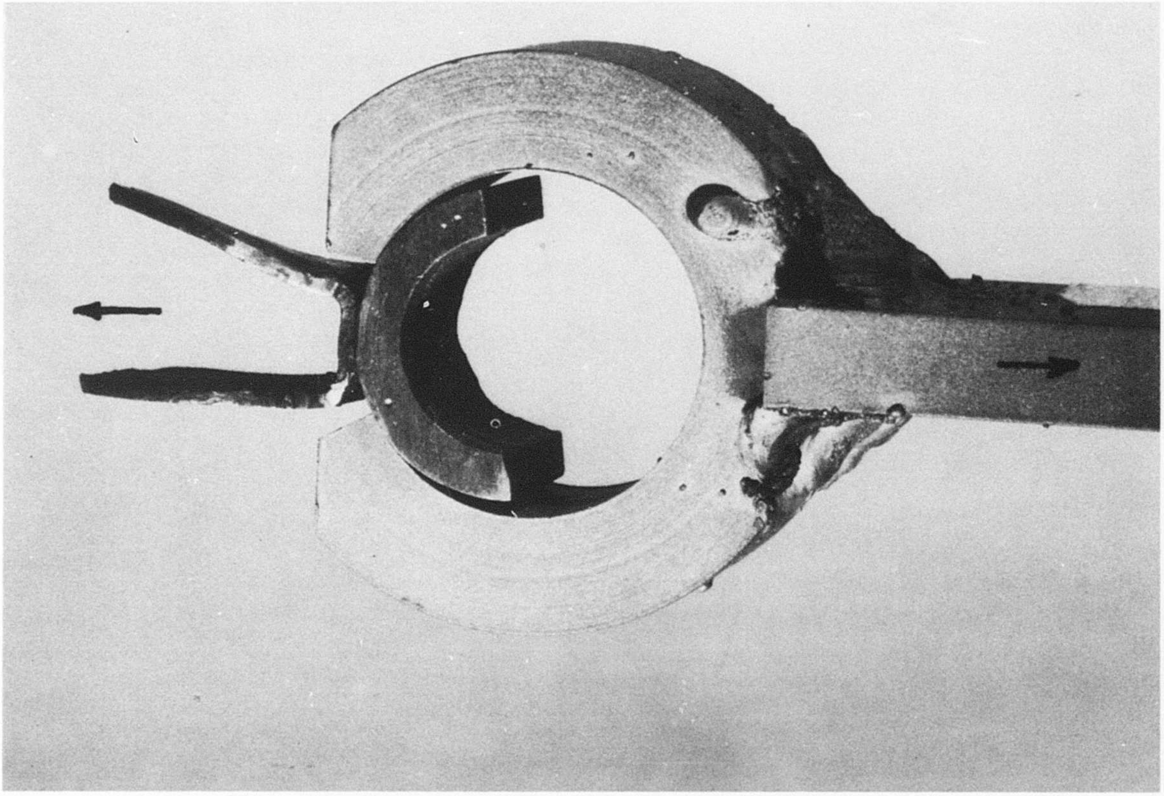


Figure 12. Fixture used to hold section of cartridge container during tensile test. The test was designed to determine the strength of the spot weld between a fin and the cartridge container support.

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